ECE421: Introduction to Machine Learning — Fall 2024

Assignment 4 – RNN, MDP, and RL

Due Date: Wednesday, Dec 4, 11:59 PM

General Notes

1. Programming assignments can be done in groups of up to 2 students. Students can be in different sections.
2. Only one submission from a group member is required.
3. Group members will receive the same grade.
4. Please post assignment-related questions on Piazza.

Group Members

Name (and Name on Quercus)	UTORid
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1 Part 1: Recurrent Neural Network (RNN)

1.1 Dataset

1.2 Implementing Single-layer Elman RNN and multi-layer LSTM RNN

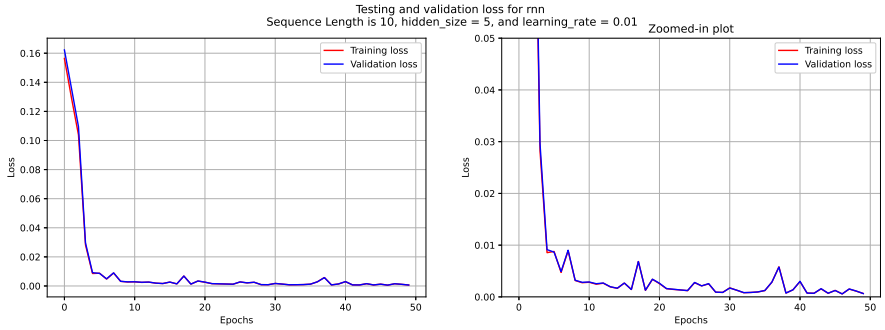
1.3 Implementing the Train Loop

1.4 Hyperparameter Tuning

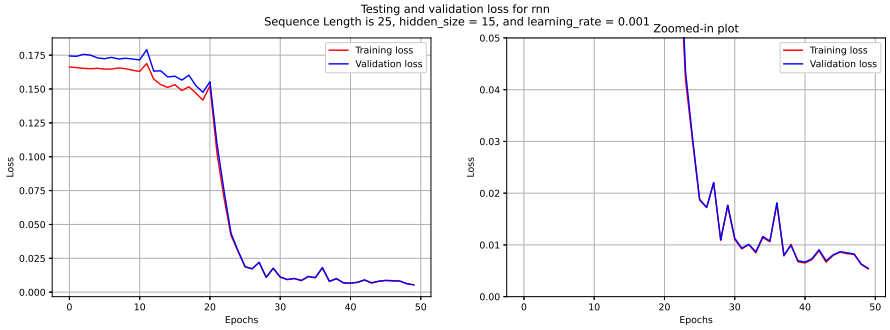
1.4.1 Question 1 (5 points): Report the Result of your Hyperparameter Tuning

In your report, include the loss figures of the best RNN and LST model that you could train. If you use the Google Colab Notebook to generate these figures, note that they are automatically saved under the `figures` folder of the assignment directory in your Google Drive. The figures are saved in eps format, which is vector file format, suitable for LaTeX. Use your favorite eps viewer/converter to view/convert these figures, if needed.

Answer.

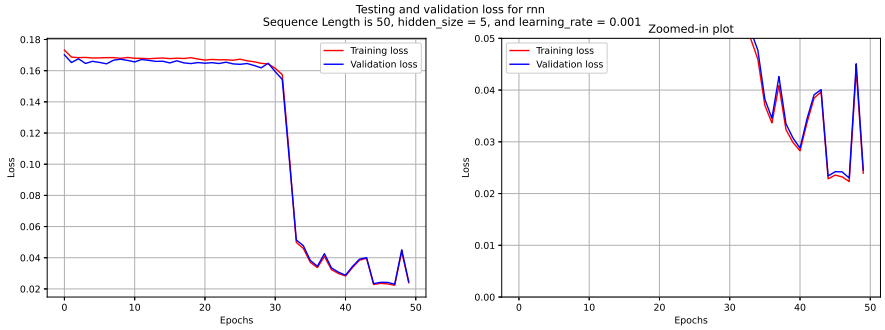


(a) RNN for sequence_length=10

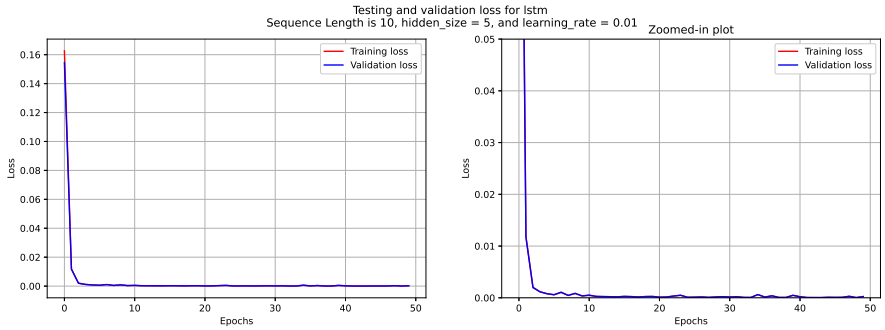


(b) RNN for sequence_length=25

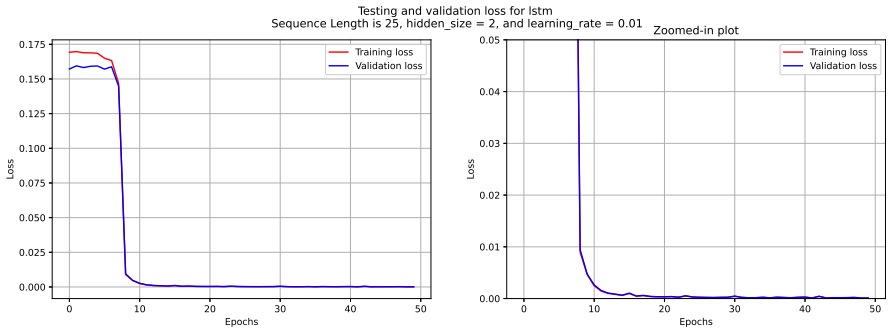
Figure 1: Loss figures of the best RNN and LST models.



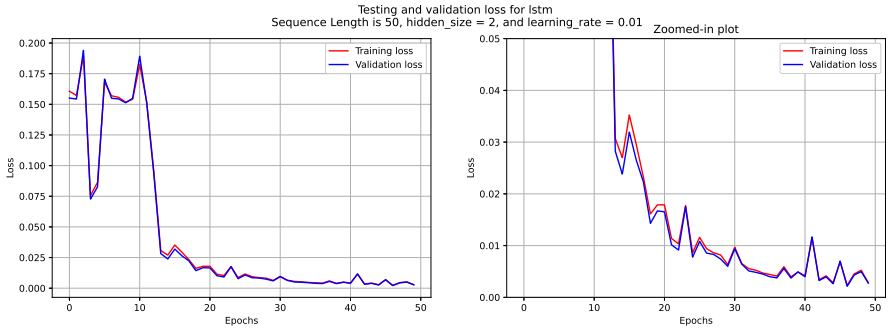
(c) RNN for sequence_length=50



(d) LSTM for sequence_length=10



(e) LSTM for sequence_length=25



(f) LSTM for sequence_length=50

Figure 1: Loss figures of the best RNN and LST model (cont.)

1.4.2 Question 2 (2 points): Why did Vanilla RNN fail?

Explain why the vanilla RNN fails to learn this simple task for the dataset with sequence length of 50? [**HINT:** You may find this article helpful.]

Answer. The reason why vanilla RNNs fail with longer sequences is due to vanishing gradient problem. When processing long sequences (like length 50), RNN network encounters challenges with gradient computation during backpropagation. These gradients can either vanish by becoming extremely small, which prevents the network from learning long-term dependencies in the data, or explode by becoming extremely large, which makes the training process unstable. This occurs because during backpropagation through time, the gradients are repeatedly multiplied across many time steps, and these repeated multiplications tend to either shrink the gradients toward zero or cause them to grow exponentially large, making it nearly impossible for the network to learn meaningful patterns across longer sequences.

1.4.3 Question 3 (5 points): Code Uploading

No written part.

2 Part 2: Markov Decision Process (MDP) and Reinforcement Learning (RL)

No written part.

3 Turning It In

You need to submit your version of the following files:

- `models.py` and `train.py`
- The modified Google Colab notebook named as `PA4.ipynb`
- `valueIterationAgents.py`, `qlearningAgents.py`, and `analysis.py`
- `PA4_qa.pdf` that answer questions related to the implementation in part 1.
- The cover file with your name and student ID filled. If you use the LaTeX template, you don't need to include the cover file separately.

Please pack them into a single folder, compress into a .zip file and name it as PA4.zip.